Armed Forces College of Medicine

AFCM

Control of Na^+ & H_2O Balance
Regulation of Plasma Volume & Osmolarity

Dr. Ghida Mohamed Hassan

,Lecturer- physiology department

Faculty of Medicine- Ain Shams university

INTENDED LEARNING OBJECTIVES (ILO)

By the end of this lecture the student should be able to:

I- Describe the renal mechanisms for sodium regulation:

- **Regulation of amount filtered**
- **Regulation of amount reabsorbed**

II- Describe the renal mechanisms for water regulation:

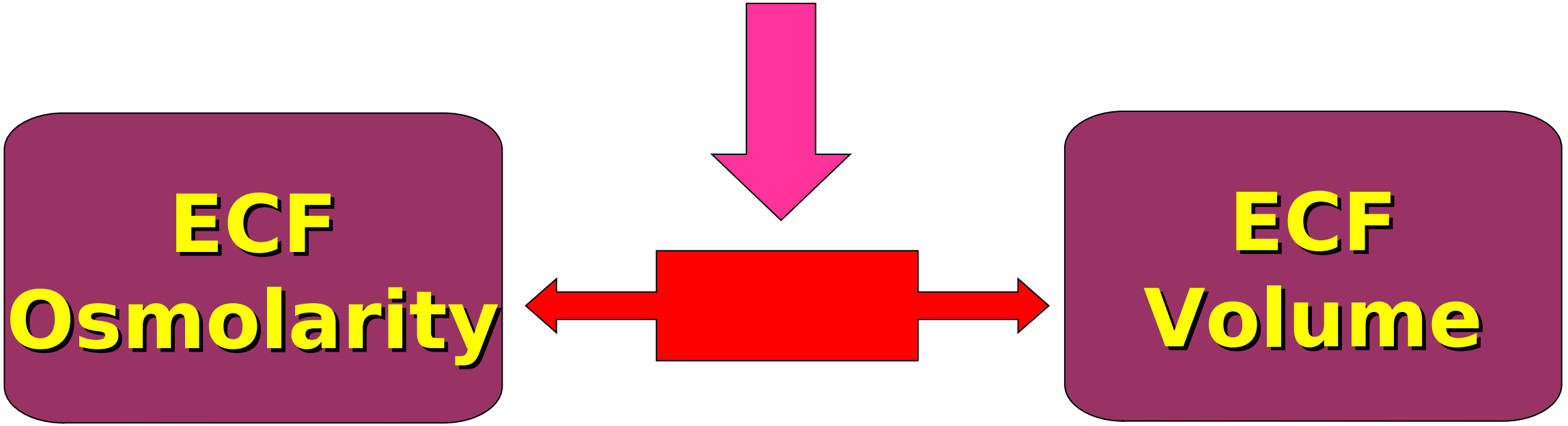
- **Role of osmoreceptors**

- **Homeostasis depends on maintaining a balance between the input and the output of all constituents present in the internal fluid environment.**

- **Regulation of fluid balance involves two separate components: control of extracellular fluid (ECF) volume, of which circulating plasma volume is a part, and control of ECF osmolarity (solute concentration).**

- **The kidneys control ECF volume by maintaining salt balance and control ECF osmolarity by maintaining water balance.**

Fluid Balance is Maintained by Controlling



Maintaining H_2O balance

↓

Regulates ECF osmolarity

↓

Prevents swelling or shrinking of cells

Maintaining salt balance

↓

Regulates ECF volume

↓

Maintain blood pressure

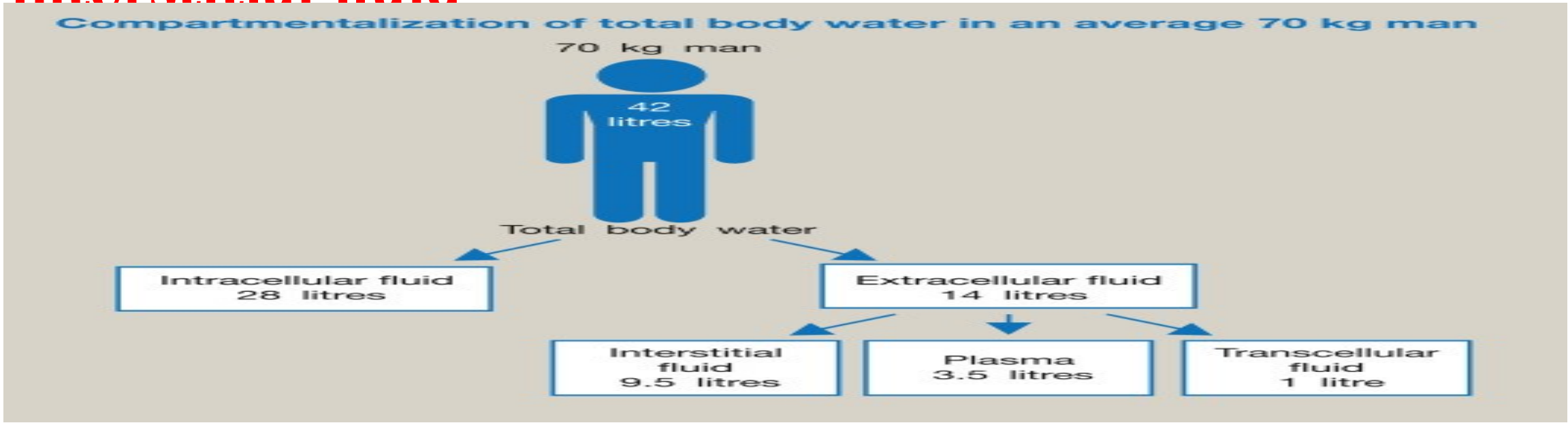
I- Body water distribution

II- Body sodium distribution

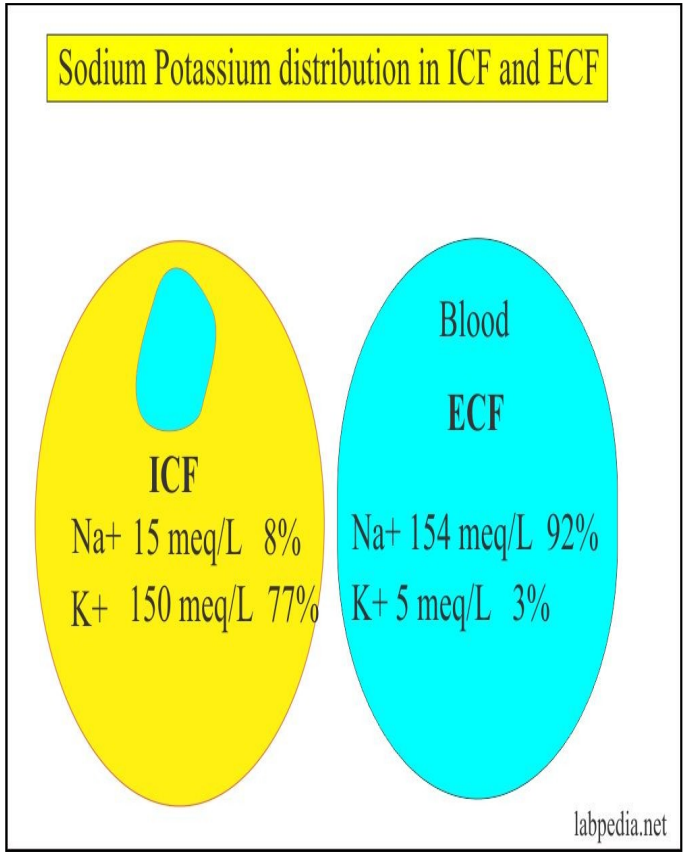
Distribution of water within the body

✓**Intracellular Fluid (ICF): The amount of water that's inside our cells accounts for 2/3rds of our TBW.**

✓**Extracellular Fluid (ECF): The amount of water that surrounds our cells accounts for 1/3 of our TBW. ECF is divided into two subcompartments: plasma and interstitial fluid**



- **There is very little sodium inside the cell (because plasma-membrane Na^+-K^+-ATPase pumps, actively transport this ion out of the cells).**
- **Approximately 50% of body sodium is in the extracellular fluid (the rest is in bone).**
- **Sodium (and its attendant anions) is the major solute of the extracellular fluid, so it is the major contributor to**



Basic renal processes for sodium and water:

- ✓ **Sodium and water are freely filtered (small molecules, not bound to proteins).**
- ✓ **Both undergo considerable reabsorption (more than 99%).**
- ✓ **They are not secreted.**
- ✓ **Sodium reabsorption is a primary active process.**
- ✓ **Water reabsorption is by osmosis and is dependent on sodium reabsorption**
- ✓ **Obligatory water loss is the minimal volume of urine water in which the excreted mass of solutes can be**

Control of ECF Volume (Defense of Volume)

- **The most important determinant of ECF volume**

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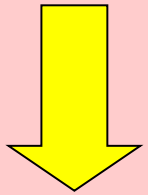
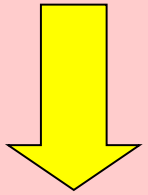
- **The amount of Na^+ in the ECF**

↑ Na^+ in ECF

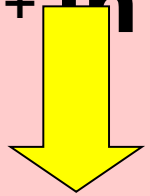


↑ H_2O in the ECF

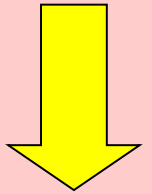


- ↑ ECF volume
- ↑ blood volume
- ↑ blood pressure

↓ Na^+ in ECF

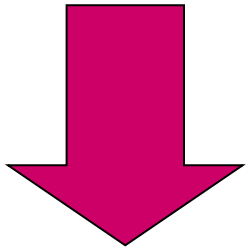


↓ H_2O in the ECF



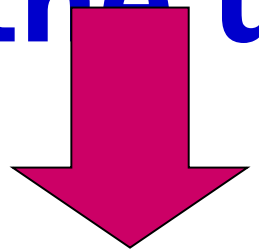
- ↓ ECF volume
- ↓ blood volume
- ↓ blood pressure

- **Controlling salt balance**



- **Regulation of ECF volume**

- **The kidneys excrete excess salt in the urine**



- **Maintain salt balance**

Renal Mechanisms for Na^+ Regulation

Regulation of Amount Filtered

- GFR

Regulation of Amount Reabsorbed

- Starling forces in PTCs
- RAAS
- SNS activity
- ANP

Regulation of Amount of Na^+ Filtered

By regulating GFR

- **Amount of Na^+ filtered (filtered load)**

= plasma Na^+ concentration X GFR

- **At any given plasma Na^+ concentration:**

any change in GFR → change amount of Na^+ that is filtered

- **Control of GFR**

→ adjust amount of Na^+ filtered each minute

↓ Na^+ load

- → ↓ ECF Volume
- →↓ blood pressure
- → ↓ GFR
- → ↓ Na^+ filtered
- → ↓ Na^+ excretion
- → Conservation of Na^+

↑ Na^+ load

- → ↑ ECF Volume
- →↑ blood pressure
- → ↑ GFR
- → ↑ Na^+ filtered
- → ↑ Na^+ excretion

Regulation of Amount of Na^+ Reabsorbed

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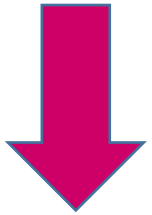
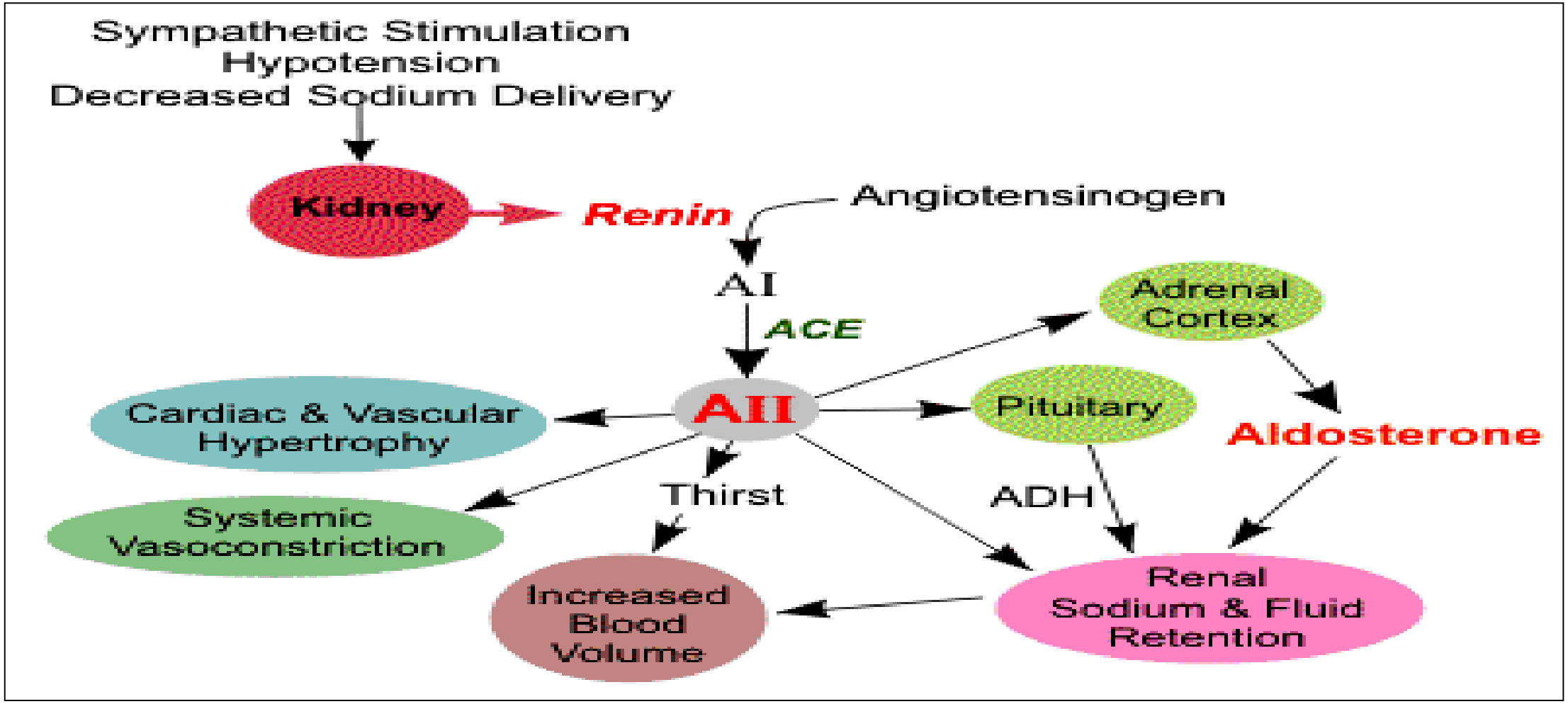
Renal Mechanisms
regulating Na^+ reabsorption and excretion



- **Renin-angiotensin-aldosterone system**
- **Sympathetic nerve activity**
- **Atrial natriuretic peptide [ANP]**

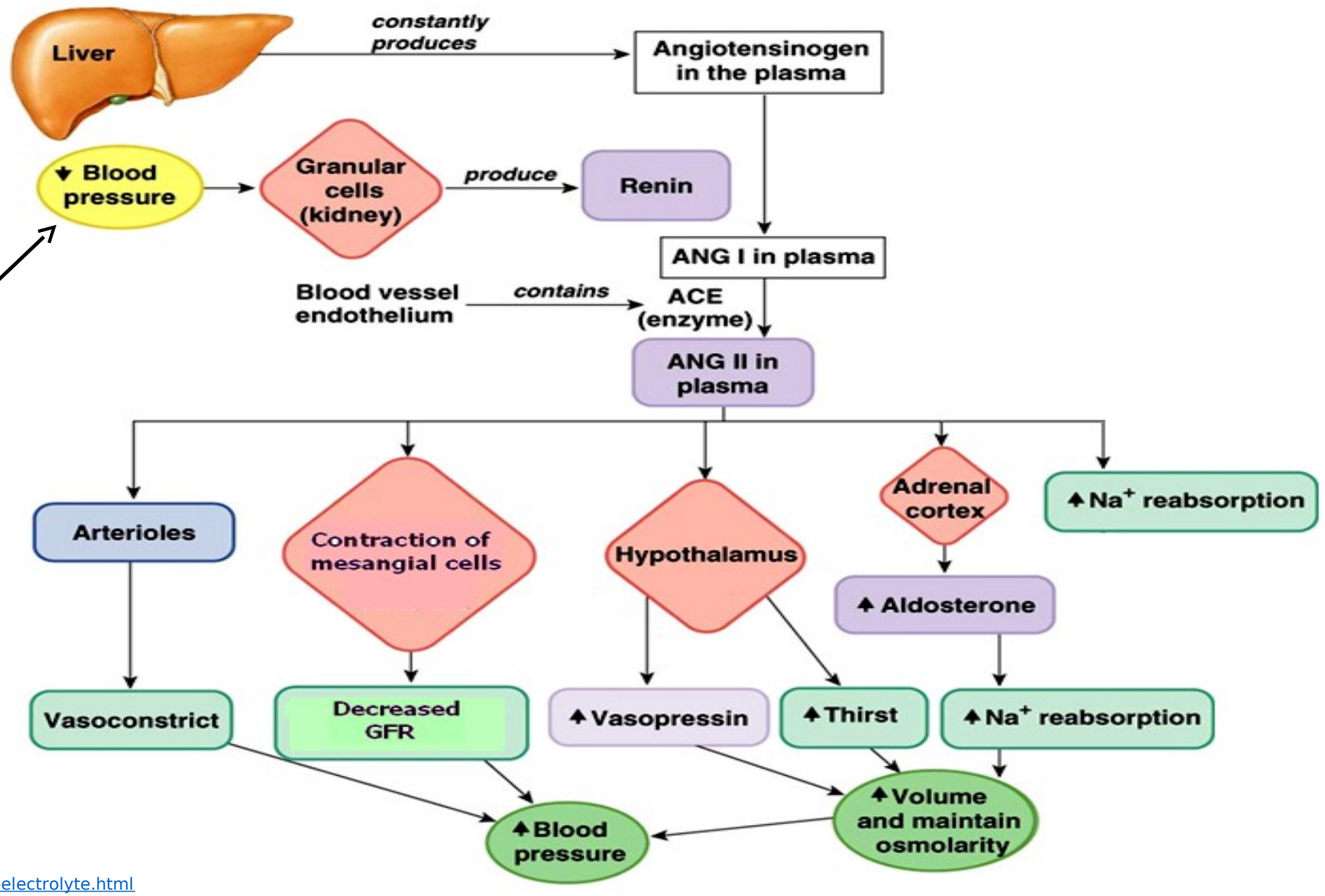
Renin-Angiotensin-Aldosterone System



http://cology4u.blogspot.com/2011/06/renin-angiotensin-aldosterone-system.html

- Dehydration
- Na^+ deficiency
- Hemorrhage

↓ ECF volume



http://tsbiomed.blogspot.com/2012/12/renal-physiology-fluid-and-electrolyte.html

Sympathetic Nerve Activity

Hypovolemia

↓

↓ arterial pressure

↓

Baroreceptor mechanism

↓

+ Renal sympathetic nerve

↓

► V.C. of afferent arterioles

→ ↓ RBF & GFR

► ↑ reabsorption of Na^+ in PCT

► Activation of RAAS

Atrial Natriuretic Peptide (ANP)

↑ ECF Volume

↓

ANP

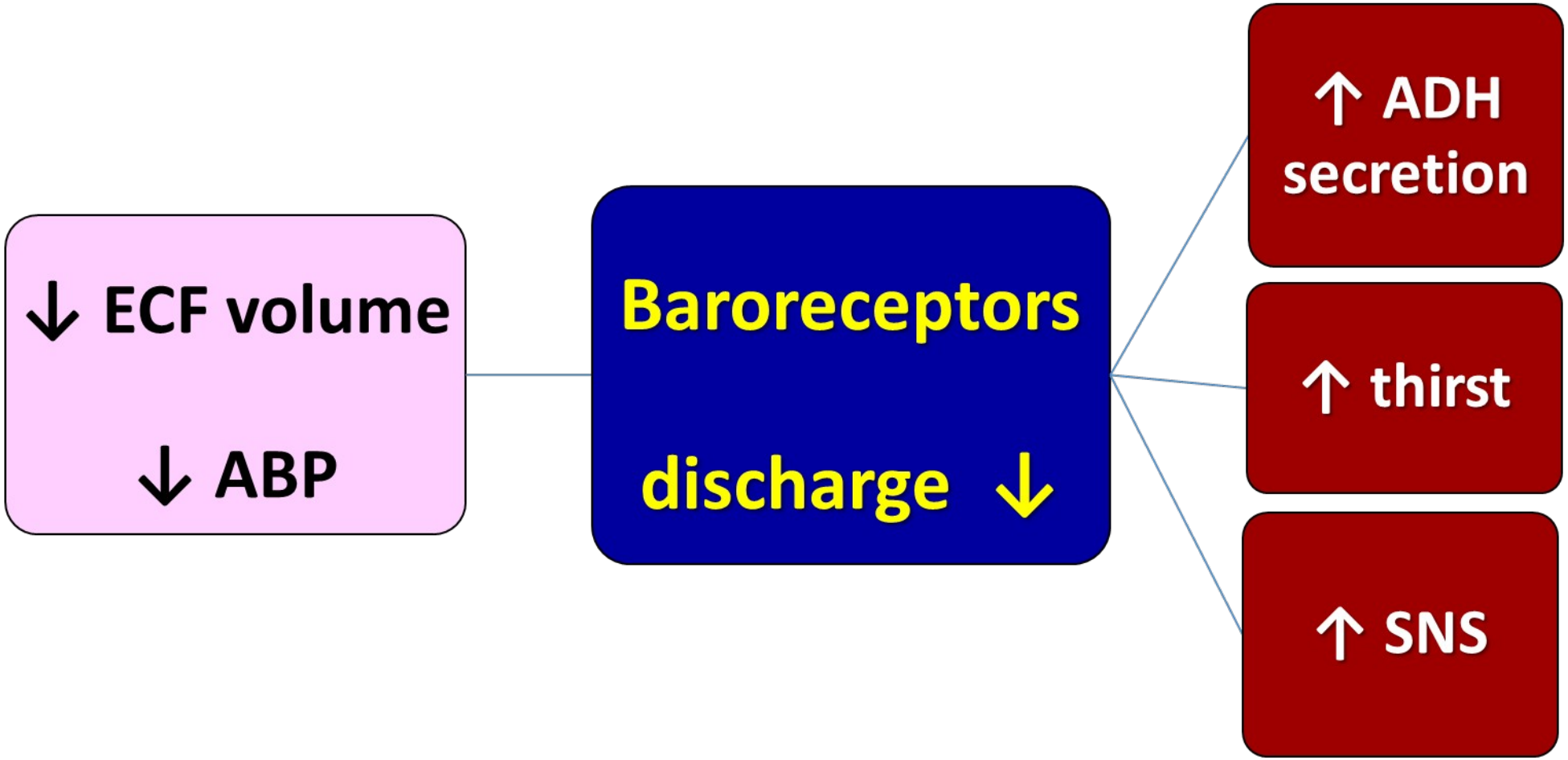
↓

- V.D. of afferent arterioles → ↑ GFR
- Relaxing mesangial cells
- ↓ Na^+ reabsorption in late DT & CD
- Inhibition of renin, aldosterone & ADH

↓

↑ Na^+ excretion (natriuresis)

Role of Baroreceptors


↓ ECF volume
↓ ABP
Baroreceptors discharge ↓
↑ ADH secretion
↑ thirst
↑ SNS

❖**Major ↓ ECF volume**

(< 7% loss of volume)

& ABP (hemorrhage)

❖**↓ stimulation of high- pressure & low-pressure baroreceptors**

❖**Stimulation of vasopressin & thirst**

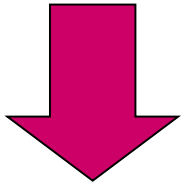
- **Hypothalamic osmoreceptors have greater influence than left atrial volume receptors in controlling vasopressin secretion and thirst**
- **A change as small as a 1% increase in ECF osmolarity**

→ ↑ vasopressin secretion

- **↑ osmolarity of 2-3% → a strong desire to drink.**

Control of ECF Volume

↓ ECF Volume



↓GFR

- ↓ ANP and related peptides
- ↓ high- & low-pressure baroreceptors firing → ↑ SNS activity , thirst & ADH
- Activation of RAAS
- Concentration of plasma protein → ↑ osmotic pressure & stimulates Na^+ reabsorption in PT

↑ ECF Volume

↑ GFR

- ↑ ANP and related peptides
- ↑ high- & low-pressure baroreceptors firing

→ ↓ SNS activity, thirst & ADH

- Inhibition of RAAS
- Dilution of plasma protein

→ ↓ osmotic pressure & inhibits Na^+ reabsorption in PT

Control of ECF Osmolarity

(Defense of Tonicity)

- **The total body osmolarity is directly proportional to total body Na^+ + total body k^+ divided by total body H_2O**
- **Changes in osmolarity of body fluids occur when a mismatch exists between amount of these electrolytes and amount of water ingested or lost from the body.**

❖**Any circumstance**

►→ **loss or gain of free H_2O that is not accompanied by comparable solute deficit or excess**

► → **changes in ECF osmolarity**

❖**ECF osmolality = 280-300 mOsm/L**

Mechanisms for Control of ECF Osmolarity

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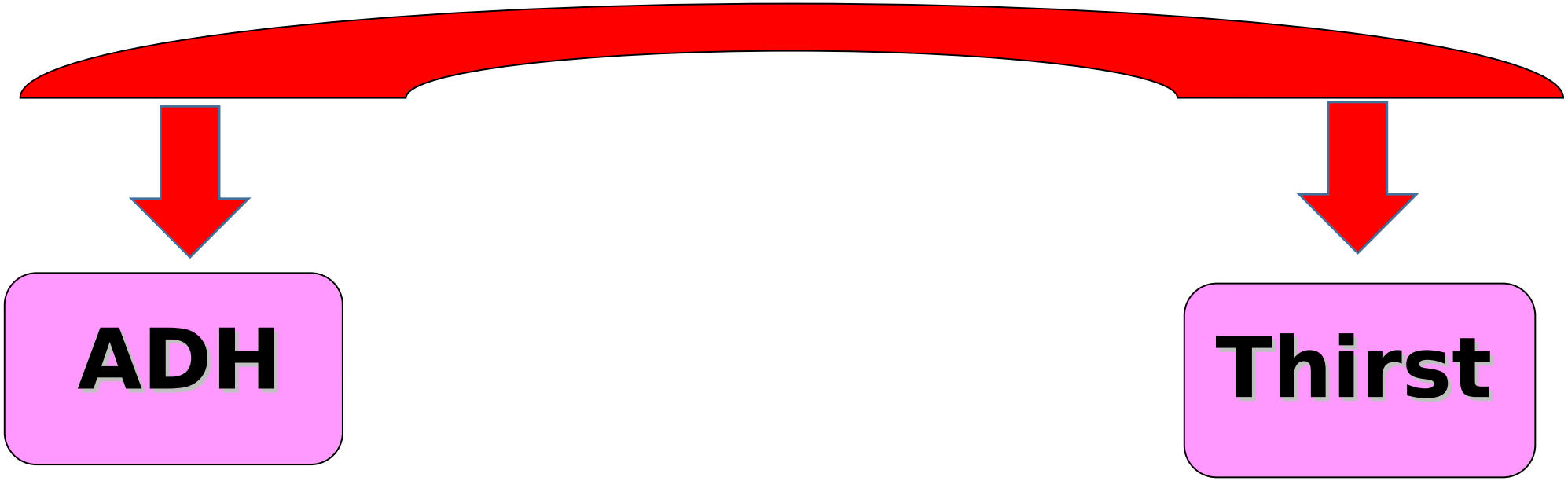
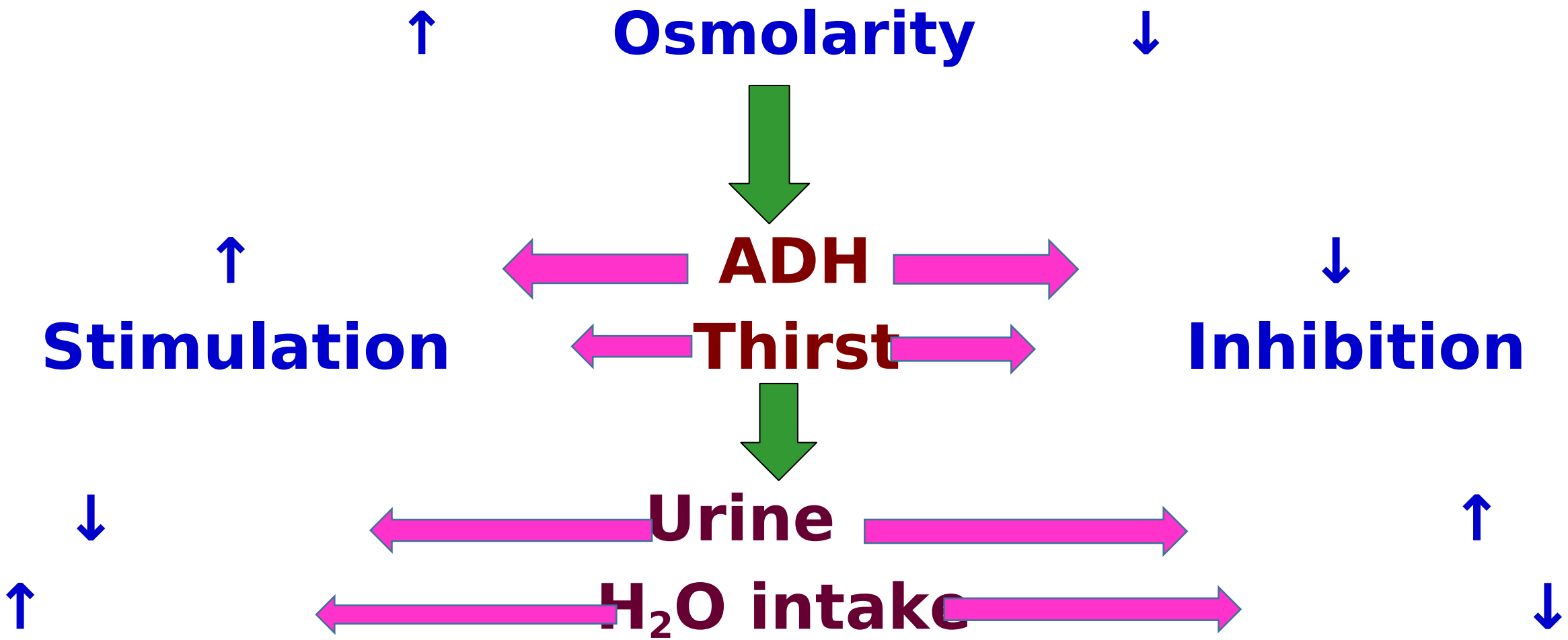
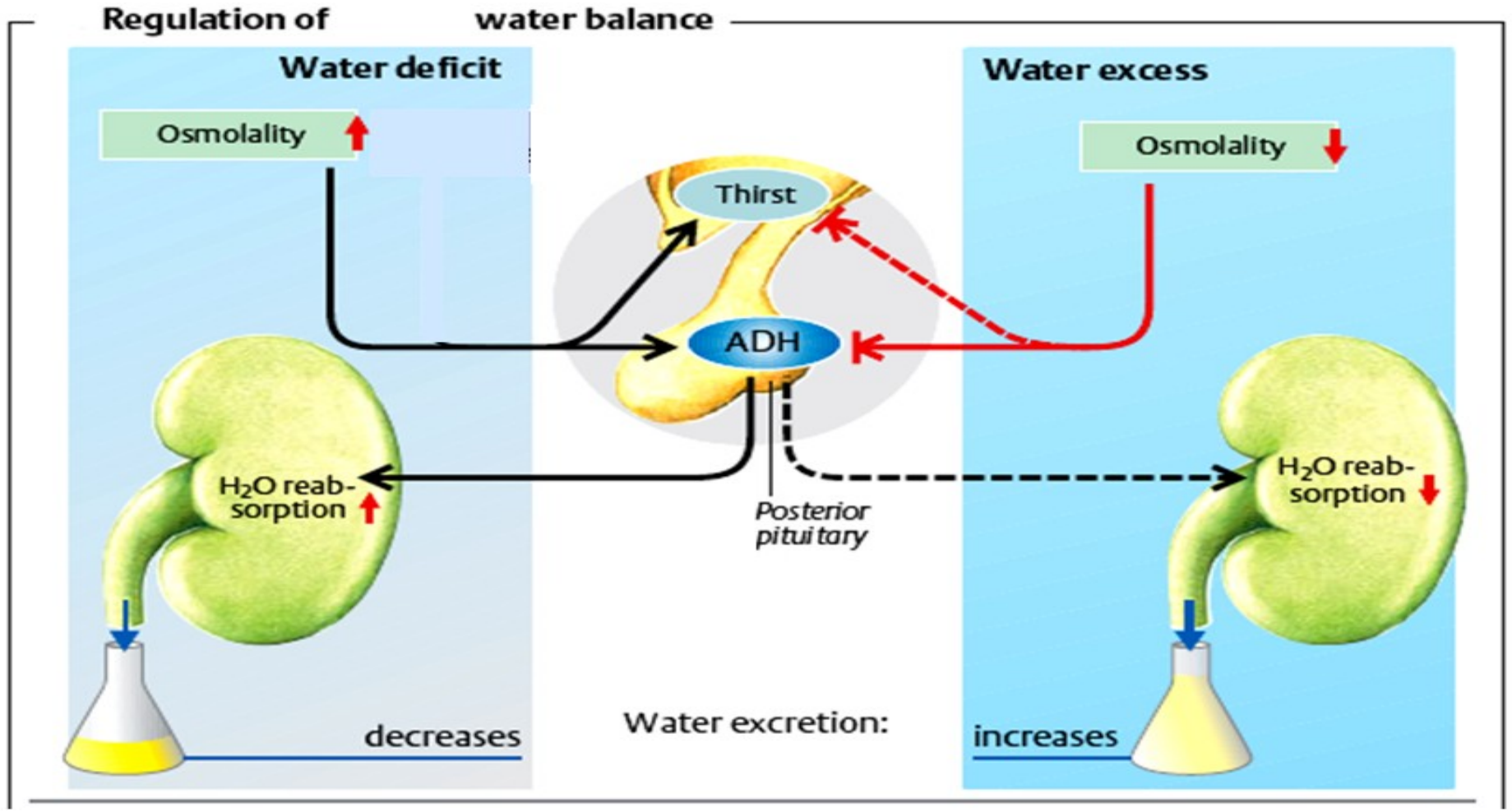
Mechanisms for Control of H_2O Balance



ECF


↑ Osmolarity ↓
↑ ADH ↓
Stimulation Thirst Inhibition
↓ Urine ↑
↑ H_2O intake ↓



https://doctorlib.info/physiology/illustrated/21.html

ADH

- → ↑ water permeability of principal cells of distal tubule and collecting duct in kidney
- → ↑ water reabsorption (via V_2 receptors)
- → ↓ urine volume

❖**Thirst center in hypothalamus**

↓

Drinking

↓

↑ water intake

Dehydration

- An ECF-free water deficit, concentrates the ECF solutes, and consequently water leaves the cell to enter the hypertonic ECF.

- Hypertonicity of the ECF, or the excessive concentration of ECF solutes, is usually associated with **dehydration.**

- **Causes:**

1- Insufficient water intake (might accompany difficulty in swallowing).

2- Diabetes insipidus, a disease characterized by ADH deficiency.

Water intoxication

- The condition of overhydration, hypotonicity, and cellular swelling resulting from excess free water retention is known as **water intoxication**.

- Swelling of the cells in the brain causes convulsions and coma and leads eventually to death.

- **Causes**

1-Excess water ingestion.

2- If water intake is not reduced after administration of exogenous vasopressin or secretion of endogenous vasopressin in response to nonosmotic stimuli (such as surgical trauma, pain, fear, nausea, head injury).

SUGGESTED TEXTBOOKS

1. Ganong’s Review of Medical Physiology. 25th editions
2. Guyton and Hall. Textbook of Medical Physiology. Thirteenth edition.
3. Introduction to Human Physiology. Lauralee Sherwood. 8th edition


Thank
you